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TropoComm — A Troposcatter Antijamming Performance Prediction Application Program for the Macintosh Personal Computer

By

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TropoComm is a troposcatter antijamming (AJ) performance prediction application program for the Macintosh personal computer. The program, intended for use in the AN/TRC-170 AJ subsystem development, allows a user to specify a troposcatter radio configuration and jammer scenario, and then generates any of the following performance prediction outputs: bit error rate (BER) curves, vulnerability contours, graphs of E_b/N_o vs J_o/N_o for a specified jammer duty cycle, and graphs of E_b/N_o vs Jammer Duty Cycle (RHO) for a specified average jammer power. The vulnerability contour graphs are generated directly by the application program. All other graphs are constructed using other programs to plot the files which are created by TropoComm. (KR)

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The primary motivation for the development of the TropoComm application program came from J. W. Graham. Without his support the development of this program would not have been undertaken. The author would like to acknowledge the contributions of Barry Nelson, who wrote a significant portion of the source code, and also Gerard E. Keough (D72), who helped with several Macintosh-related programming problems.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION 1

INTRODUCTION

TropoComm is a troposcatter antijamming (AJ) performance prediction application program for the Macintosh personal computer. This application program allows a user to specify a radio and jammer scenario, e.g., electronic countermeasures (ECM), and then generates any of the following four types of performance prediction outputs: bit error rate (BER) curves, vulnerability contours, graphs of E_b/N_0 vs J_0/N_0 for a specified jammer duty cycle, and graphs of E_b/N_0 vs Jammer Duty Cycle (RHO) for constant transmitted jammer power. The vulnerability contour graphs are generated directly by the application program. All other graphs are constructed using the Cricket Graph application program to graph the text files which are created by the TropoComm program. The present version of TropoComm has several internal parameters which have been tailored to the AN/TRC-170 radio.

1.1 Scope

This document introduces potential users to the various ways that the TropoComm program can predict radio performance. The document is not an attempt to derive or justify the mathematical model which forms the basis of the program.

Section 1 provides general background material regarding TropoComm. Sections 2 through 5 address the following topics: the four major algorithms in the program, the Macintosh interface, and the definition of all the necessary input variables. An example of each algorithm input and output has also been included.

1.2 TropoComm Algorithms

The TropoComm program consists of the following four algorithms: the BER algorithm, the vulnerability algorithm, the E_b/N_0 vs J_0/N_0 algorithm, and the RHO algorithm. The higher level structure for calling and disposing of each of the four algorithms is contained in the main program control loop. A flow chart of this control loop has been included as an aid and is shown in figure 1. All four algorithms require the user to specify a radio and jammer scenario. Then, depending on the algorithm selected, the program generates one of the following outputs: a text file containing BER vs E_b/N_0 values, a plot of a vulnerability contour, a text file containing E_b/N_0 vs J_0/N_0 values, or a text file containing E_b/N_0 vs Jammer Duty Cycle values. Although only the vulnerability algorithm generates the desired graphic output directly, the process of converting the text files into graphs has been somewhat automated. A graphics application program, Cricket Graph, can be used to read the text files created by TropoComm and then generate the desired output graphics.

Considerable effort has been made to create a user interface which is consistent with the standard Macintosh interface. In order to implement this type of an interface, the program makes extensive use of the Macintosh Toolbox. For those wishing more information on the Toolbox see references [1] and [2].

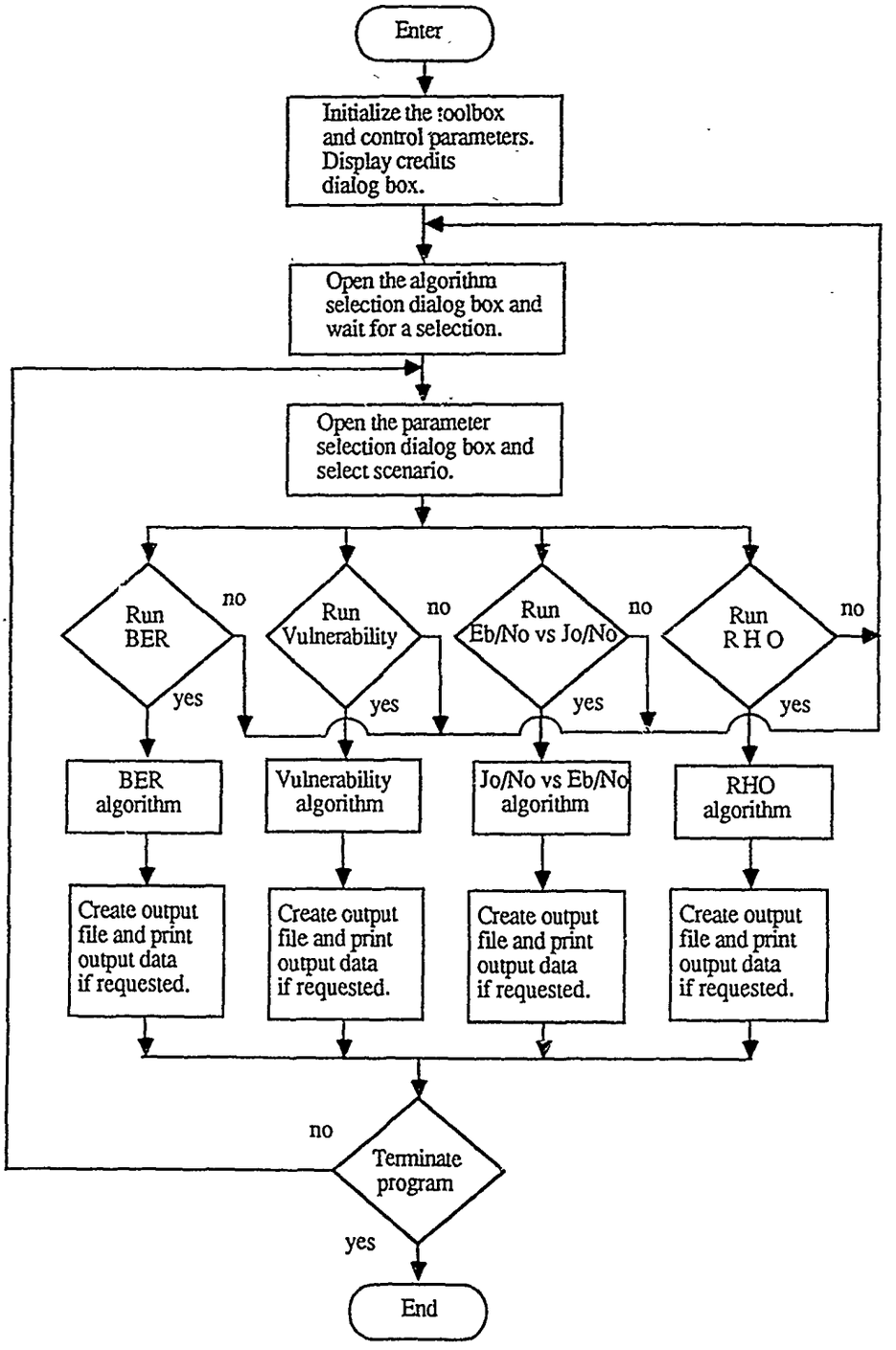

Figure 1. TropoComm Program Flow Chart

To run the TropoComm program, activate the TropoComm application icon. A dialog box will appear which states the date and version of TropoComm which is running. This dialog box remains on the screen for approximately six seconds and is then replaced by the algorithm selection dialog box (see figure 2). Sections 2 through 5 contain the instructions and parameter descriptions necessary to run the algorithm which you select.

1.3 Recommended System Configuration

The recommended system configuration is the system configuration on which the TropoComm application program was developed. The following hardware and software is recommended:

Hardware

Macintosh II personal computer
80 Megabyte hard disk
LaserWriter II NT

Software

Finder v 6.1
System v 6.0.2
LaserWriter v 5.1
LaserPrep v 5.1
MacDraw v 1.9.6
MacDraw II v 1.1
Cricket Graph v 1.3

TropoComm has also run on the Macintosh Plus and the Macintosh SE personal computers using other versions of the Finder and System. It has also run using the older LaserWriter, the ImageWriter, and the ImageWriter II, for output devices. Software development of TropoComm was done in Turbo Pascal [3] version 1.1 from Borland International. Run time on the Macintosh Plus and SE without the math coprocessor will be long when using the vulnerability contour algorithm.

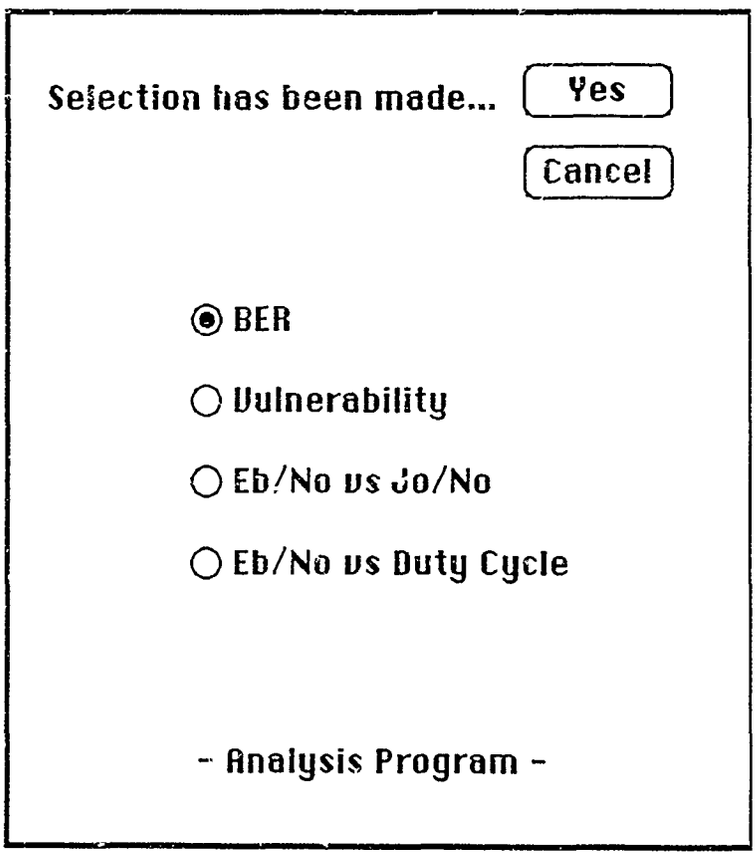

Figure 2. The Algorithm Selection Dialog Box

SECTION 2

THE BER ALGORITHM

For the reader wishing to explore the model used in the TropoComm, the BER algorithm is a good place to start. By varying a selected parameter value and plotting the results on a BER curve, the effects of this parameter are much easier to understand. Parameters of particular interest are those which, when set at or near their limits, yield insight into the structure of the model. Examples of these parameters include implicit diversity, suppression, and jammer power. The BER curve is a good example for gaining insight into what's happening.

The BER algorithm selects an appropriate closed-form BER expression for a specified scenario and solves this expression for a range of E_b/N_0 values. E_b/N_0 spans a range from 0 to 40 dB in 2 dB increments; therefore, a maximum of 21 values will be calculated. The BER algorithm also permits specification of one particular BER of interest, which must be less than 0.5 and greater than 10^{-6}, and uses a searching algorithm to find the required E_b/N_0 within an accuracy of +0/-1 percent.

To run the BER algorithm, first select the BER button in the algorithm selection dialog box, figure 2, and then activate the YES control button. The BER parameter selection dialog box will appear next with a predetermined set of default values for the radio and jammer parameters. Changes can now be made to any of the radio or jammer parameters, including the option of turning the jammer off. After the desired radio and jammer scenario has been entered, activate the RUN control button to start the calculations. While the calculations are in progress, a dialog box is displayed which contains a CANCEL control button, a "Please wait " message, and a circle which is periodically filled in to indicate the percentage of calculations completed. When the calculated BER is less than 10^{-6}, the calculations are terminated since the BER can only get smaller and is beyond our range of interest. If the CANCEL button is selected while the calculations are in progress, the TropoComm program terminates and control is returned to the Macintosh operating system. When the algorithm completes all of the calculations, or the calculated BER is less than 10^{-6}, the screen is cleared and a text window with the output data is displayed.

2.1 The BER Parameter Selection Dialog Box

The BER parameter selection dialog box, figure 3, is partitioned into four sections: radio parameters, jammer parameters, calculated values, and control buttons. The radio parameter and jammer parameter sections permit specification of various scenarios. A more detailed discussion of these sections is provided in the next paragraph. The calculated values section is used to display the information rate for the scenario that has been specified. The information rate is the data rate used in determining the received signal level associated with a calculated E_b/N_0 value. The control buttons section contains the name of the algorithm and four control buttons: the RUN button starts the BER calculations, the CANCEL button returns the program to the algorithm selection dialog box, the YES button changes the radio and jammer defaults to the values currently shown in the parameter selection dialog box, and the DEFAULTS button resets all radio and jammer parameters to the default values.

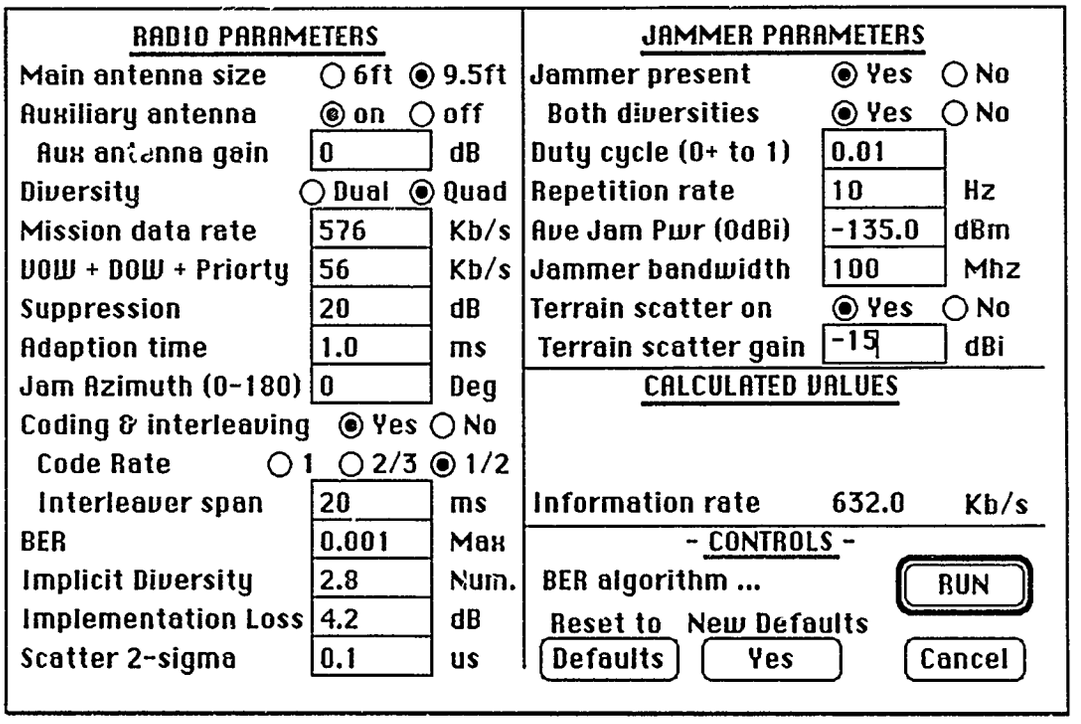

Figure 3. The BER Parameter Selection Dialog Box

Selecting various radio and jammer scenarios requires a change to the radio and/or jammer parameter default values. A short discussion of these parameters follows. There are 16 radio paramcters:

1. The main antenna diameter can be either 6 ft or 9.5 ft. This reflects the present antenna options for the AN/TRC-170 radio. There are approximations to both the 6 ft and 9.5 ft antenna gain patterns embedded in the TropoComm program. The antenna gain at the specified jammer azimuth is used in determining the received jammer power.

2. The auxiliary antenna can be either ON or OFF.

3. If the auxiliary antenna is ON, then a gain (which is relative to the main antenna gain) has to be specified. If the gain is set to zero dB, then the gain of the auxiliary antenna equals that of the main antenna, except on the mainbeam, where it is set equal to the gain of the first sidelobe of the main antenna. If a gain other than zero dB is specified, then this number is simply added to the gain of the main antenna, except on the mainbeam, where it is added to the gain of the first sidelobe of the main antenna.

4. There is a choice of either dual or quad explicit diversity. Dual diversity is dual space diversity and quad diversity is dual space and dual frequency diversity.

5. The mission data rate can be set to any value greater than or equal to zero, provided that the sum of the mission data rate plus the VOW + DOW+ priority data rate is greater than zero.

6. The voice-order-wire (VOW)+ data-order-wire (DOW) + priority data rate can be set to any value greater than or equal to zero, provided that the sum of the mission data rate plus the VOW + DOW + priority data rate is greater than zero. The priority data channel is intended to allow for a radio configuration with a 32 Kb/s survivable channel.

7. Suppression can be set to any positive value and is a measure of the ability of the adaptive suppression algorithm to suppress the jammer. The suppression value is the maximum factor (in dB) that the jammer can be suppressed.

8. Adaptation time is the time it takes for the suppression algorithm to adapt. Jammers with pulse widths less than the adaptation time cannot be suppressed by the suppression algorithm.

9. The jammer can be located at any azimuth between 0 and 180 degrees relative to boresight on the main antennas. The main antenna gain pattern has been approximated using straight lines connecting 21 break points. All specified jammer azimuths will be mapped into one of these 21 break points. The 21 break points have a total of 13 different gains. See table 1 for the mapping between jammer azimuth and antenna gain. Note, because symmetry is assumed, the 0 to 180°span actually implies the full 360° coverage.

Table 1. Jammer Azimuth vs Antenna Gain

6 Ft. Main Antenna		9.5 Ft. Main Antenna	
Jammer Azimuth (Deg.)	Antenna Gain (dB)	Jammer Azimuth (Deg.)	Antenna Gain (dB)
$0 \leq AZ \leq 3$	36	$0 \leq AZ \leq 2$	40
$3 < AZ \leq 5$	16	$2 < AZ \leq 4$	15
$5 < AZ \leq 10$	6	$4 < AZ \leq 10$	11
$10 < AZ \leq 20$	-1	$10 < AZ \leq 20$	5
$20 < AZ \leq 30$	-8	$20 < AZ \leq 30$	-1.5
$30 < AZ \leq 70$	-8	$30 < AZ \leq 40$	-8
$70 < AZ \leq 80$	-2	$40 < AZ \leq 80$	-8
$80 < AZ \leq 90$	-1	$80 < AZ \leq 90$	-5.4
$90 < AZ \leq 100$	1	$90 < AZ \leq 100$	-2.8
$100 < AZ \leq 110$	2	$100 < AZ < 110$	0
$110 < AZ \leq 120$	-5	$110 < AZ \leq 125$	-13
$120 < AZ \leq 130$	-12	$125 < AZ \leq 130$	-13
$130 < AZ \leq 180$	-12	$130 < AZ < 180$	-13

10. Coding and interleaving can either be ON or OFF. No coding and interleaving is the same as a code rate of one.

11. Code rates of 1, 2/3, or 1/2 can be selected.

12. If a code rate of 2/3 or 1/2 has been selected, an interleaver span must be specified.

13. A BER, which must be less than 0.5 and greater than 10^{-6}, can be specified, and the algorithm will solve for the corresponding E_b/N_0 to within an accuracy of +0/-1 percent.

14. The implicit diversity of the channel can be set to various values. An implicit diversity of one is a flat-fading channel, and a large implicit diversity approximates a nonfading channel.

15. Implementation loss can be specified.

16. The scatter 2-sigma is the dispersion of pulse jammer terrain scatter due to multipath out to the radio horizon. If the jammer duty cycle is one, then the scatter 2-sigma has no meaning.

There are eight jammer parameters:

1. The jammer can be either ON or OFF.

2. If quad diversity was selected as the radio configuration, then the jammer can be on one or both of the frequency diversity channels.

3. The duty cycle of the jammer can be specified from 0^+ to 1.

4. If the duty cycle is less than one, then the repetition rate must be specified.

5. The average jammer power received by a 0 dBI gain antenna at the radio site must be specified.

6. Jammer bandwidth is selectable. The shape of the jammer spectrum is assumed to be rectangular.

8. If the terrain scatter is ON, the terrain scatter gain relative to a 0 dBI antenna must be specified. This gain applies to the average jammer power (item 5 above).

2.2 BER Menu Options

When the BER calculations have been completed, a text window with E_b/N_0 versus BER values is displayed. The screen view of this text window has the following format. The first line contains two pair of numbers. The first pair is the E_b/N_0 and BER for the smallest E_b/N_0 output value. The second pair in the first line corresponds to the BER which was specified in the parameter selection dialog box. This line is followed by the remaining data starting with the second smallest E_b/N_0 value.

Associated with the text window are three menu options: the apple menu, the file menu, and the edit menu. The apple menu allows access to any of the desk accessories which are currently installed. The file menu allows you to save a file, print the displayed data along with the scenario, or quit. When you save a file you will be given the option of saving a text file and/or a PICT file. Saving the text file will allow you to transfer the output data into other Macintosh applications later on. Note, if the text file that is going to be saved is to be opened up in the Cricket Graph application, then the first two lines of the text window must be deleted before saving the file. If the PICT file is saved, it is saved as a MacDraw document, and when activated later on will open up as such; the MacDraw application program has to be on the hard disk in order to open a MacDraw document. The PICT file is a picture of the BER parameter selection dialog box and the output data. The print command under the window file menu allows you to print the BER parameter selection dialog box and the output data while the text window is still displayed. For an example of the print command output, see figure 4. The quit command, which is also under the window file menu, returns you to the parameter selection dialog box. The window edit menu allows you to cut, copy, and paste between the clipboard and the text window.

2.3 BER Output Graphics

Cricket Graph is a Macintosh application program used for making various types of graphs. Text files which have been created using the save command in the BER algorithm can be transferred directly to Cricket Graph by simply opening the text file with the application program running. This provides a convenient way of getting the data from the BER algorithm to the Cricket Graph application.

To create a graph, first quit the TropoComm program and then activate the Cricket Graph application. In the Cricket Graph menu under 'File', choose 'Open file'. Set the option to 'show all text files'. Then open the file which was previously created by the BER algorithm. The data will automatically be transferred into the Cricket Graph application, and an appropriate graph can be constructed and then saved, printed, or discarded. Using the output data in figure 4, an example of a graph created using Cricket Graph is shown in figure 5.

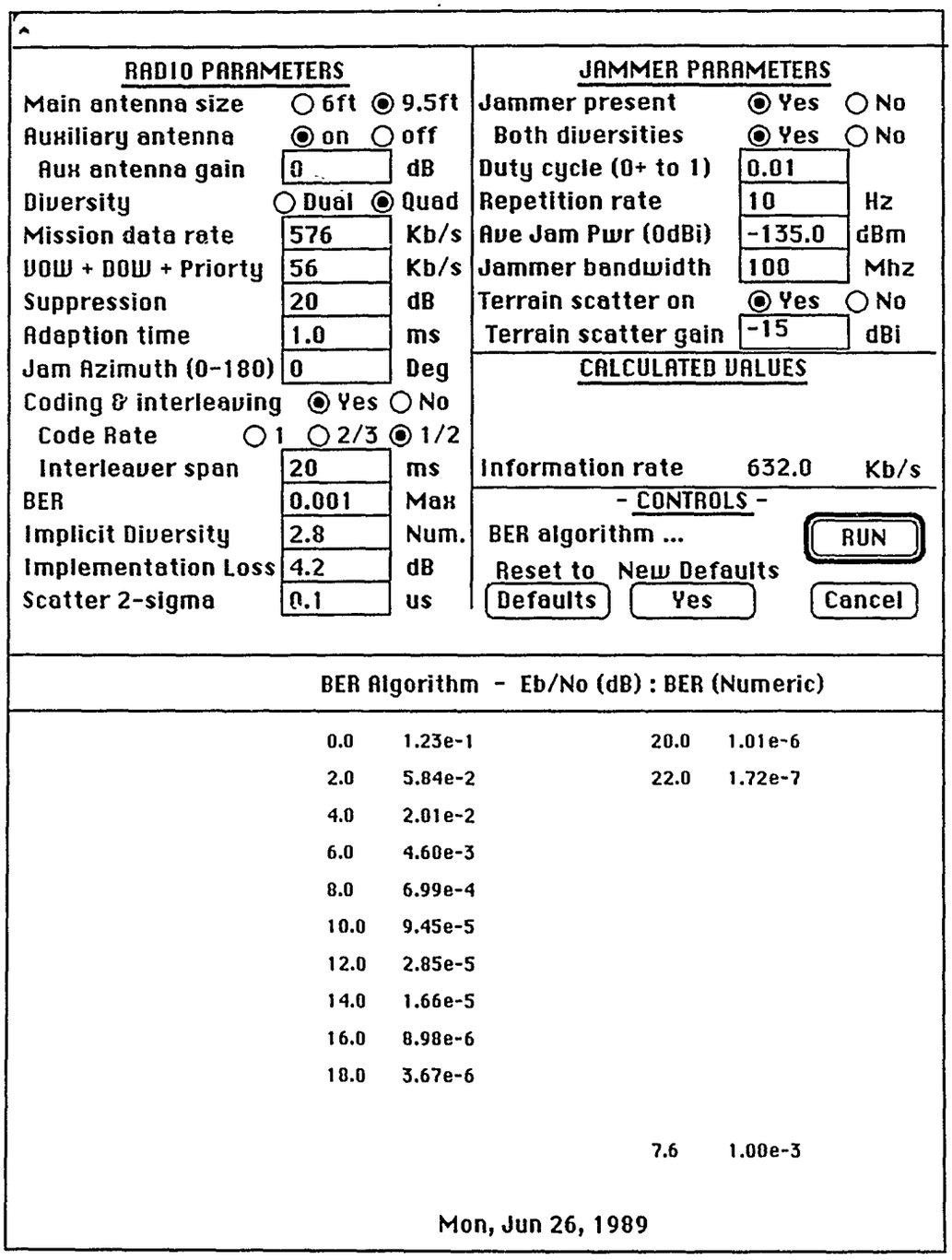

Figure 4. BER Print Command Output

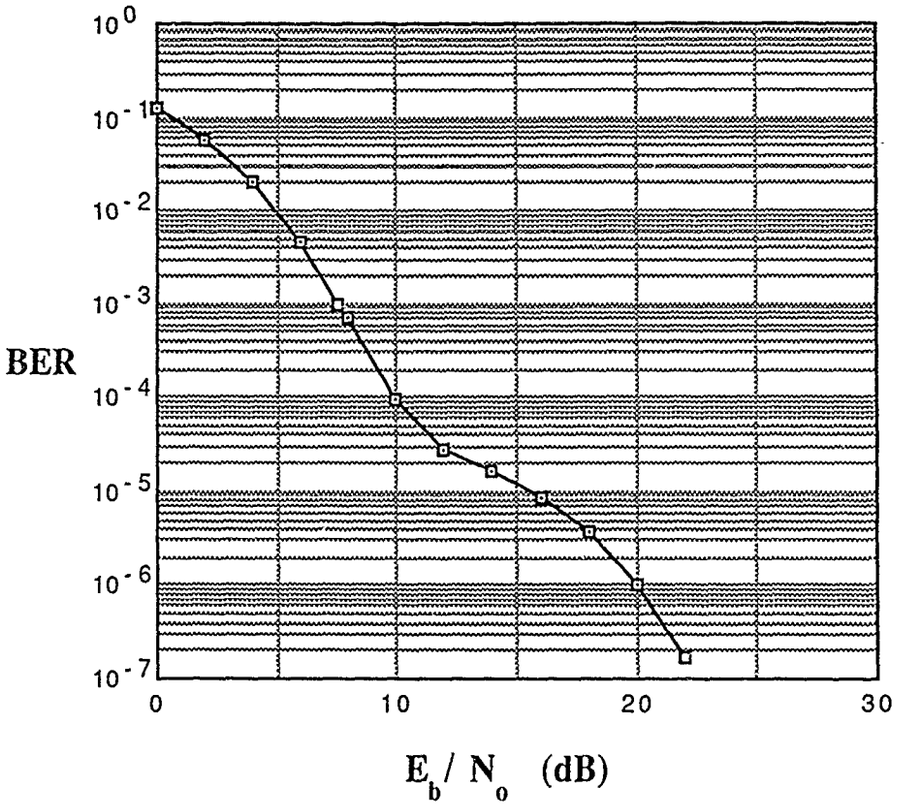

Figure 5. BER Curve

SECTION 3

THE VULNERABILITY ALGORITHM

The vulnerability algorithm generates an output which is a two-dimensional plot of a contour of constant BER. It is assumed that if the jammer is within this contour that the radio is jammed. Unlike the other algorithms in TropoComm, the vulnerability algorithm produces output graphics directly. A brief description of the algorithm follows.

The vulnerability algorithm selects the appropriate BER expression for the scenario specified. For a predetermined set of azimuths, it uses this BER expression and searches for the J_O/N_O value which yields a BER to within an accuracy of +0/-1 percent of the BER specified in the parameter selection dialog box. This J_O/N_O value is then scaled by the antenna gain. The difference between the resulting J_O/N_O and the J_O/N_O at the jammer site is the line-of-sight path loss. The jammer distance is determined directly from the path loss. This process is repeated for a total of 42 different azimuths, and the resulting data points are connected together with straight lines to form a contour of constant BER. There are two possible error messages which the vulnerability algorithm can generate. If a J_O/N_O value greater than 80 dB is required, an error message is generated stating that the J_O/N_O value has been set to 80 dB and the actual BER is less than the specified BER. The jammer distance is then calculated from a path loss which is the difference between the 80 dB and the J_O/N_O in dB at the jammer site. The upper limit is presently set to 80 dB because this is the point at which the front end of the AN/TRC-170 saturates. The other error message is a result of an insufficient RSL. If the required J_O/N_O is less than -30 dB, then a message is generated stating that the RSL is not sufficient to achieve the required BER performance.

To run the vulnerability algorithm, select the vulnerability button in the algorithm selection dialog box, figure 2, and then activate the YES control button. The vulnerability parameter selection dialog box will appear next with a predetermined set of default values for the radio and jammer parameters. Changes can now be made to any of these parameters except that the jammer cannot be turned OFF. After the desired radio and jammer scenario has been entered, activating the RUN control button starts the calculations. While the calculations are in progress, a dialog box is displayed which contains a CANCEL control button, a "Please wait " message, and a circle which is periodically filled in indicating the azimuth calculations which have been completed. If the CANCEL button is activated while the calculations are in progress, the TropoComm program terminates and control is returned to the Macintosh operating system. When the algorithm completes all of the calculations, the screen is cleared and a graphics window with a contour is displayed.

3.1 The Vulnerability Parameter Selection Dialog Box

The vulnerability parameter selection dialog box, figure 6, is partitioned into four sections: radio parameters, jammer parameters, calculated values, and control buttons. The radio parameters and jammer parameters sections will allow you to specify various scenarios. A more detailed discussion of these sections is provided below. The calculated values section contains three items: maximum scatter

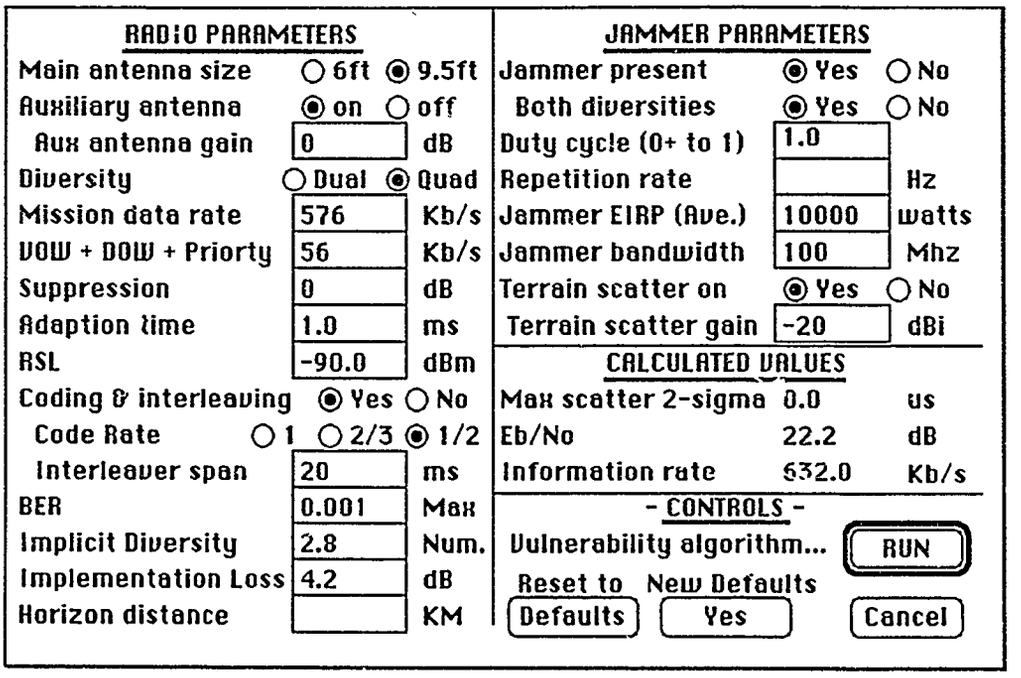

Figure 6. The Vulnerability Parameter Selection Dialog Box

2-sigma, E_b/N_0, and information rate. The maximum scatter 2-sigma value is only defined when a pulse jammer is specified, and reflects the spreading of the terrain scatter pulse due to the time delay associated with the jammer pulse being scattered continually from terrain all the way out to the radio horizon and back again. The dominant source for the scatter 2-sigma value is jammer scatter from within the mainbeam, making this an azimuth-dependent value. Maximum scatter 2-sigma will always occur when the jammer is positioned 180° relative to boresight on the main antennas. The E_b/N_0 value in the calculated values section is computed by the program using both the RSL which was specified in the parameter selection dialog box and the information rate. Information rate is defined as the sum of the mission data rate and the VOW + DOW + Priority data rate. The control buttons section contains the name of the algorithm and four control buttons: the RUN button starts the vulnerability calculations, the CANCEL button returns you to the algorithm selection dialog box, the YES button changes the radio and jammer default values to the values currently shown in the parameter selection dialog box, and the DEFAULTS button resets all radio and jammer parameters to the default values.

Selecting various radio and jammer scenarios requires a change to the radio and/or jammer parameter default values. There are 16 vulnerability radio parameters, and they are identical to the BER radio parameters described earlier in section 2.1, except for items 9 and 16. Items 9 and 16 are now

9. RSL is the received-signal level at the main antenna output and is the signal power used in determining the E_b/N_0 value in the calculated-values section.

16. Horizon distance is the radio horizon distance on boresight of the main antennas. This value is used to calculate the maximum scatter 2-sigma value in the calculated-values section.

There are eight vulnerability jammer parameters, and they are identical to the BER jammer parameters described earlier in section 2.1, except for item 5. Item 5 is now

5. Jammer EIRP is the average effective isotropic radiated power at the jammer site in the direction of the radio.

3.2 Vulnerability Menu Options

When the vulnerability calculations have been completed, a vulnerability contour is displayed on the screen using a standard Macintosh graphics window. There are two pages of output, and the graphics window can be scrolled over both of them. The first page contains the contour, and the second page contains the parameter selection dialog box and the calculated contour data points. Scroll to the right to view the second page.

Associated with the graphics window are three menu options: the apple menu, the file menu, and the edit menu. The apple menu allows access to any of the desk accessories currently installed. The file menu allows you to save a file, print the contour and scenario selected, or quit. When you save a file, you will be saving the currently displayed graphics window as a PICT file. If you save the PICT file, it

is saved as a MacDraw document, and when activated later on will open up as such. The MacDraw application must be on the hard disk in order to open up a MacDraw document. The print command allows you to print the vulnerability contour, the parameter selection dialog box, and the calculated data points. For an example of the print command output, see figure 7 and figure 8. The quit command returns you to the parameter selection dialog box. The edit menu allows you to copy the graphics window to the clipboard from which you can paste the window into a MacDraw document.

3.3 Vulnerability Output Graphics

The TropoComm program has four different algorithms which are used to generate four different graphs. Three of these algorithms require an additional applications program, Cricket Graph, to generate the desired graphics. The vulnerability algorithm generates the graphics directly. Examples are shown in figure 7 and figure 8.

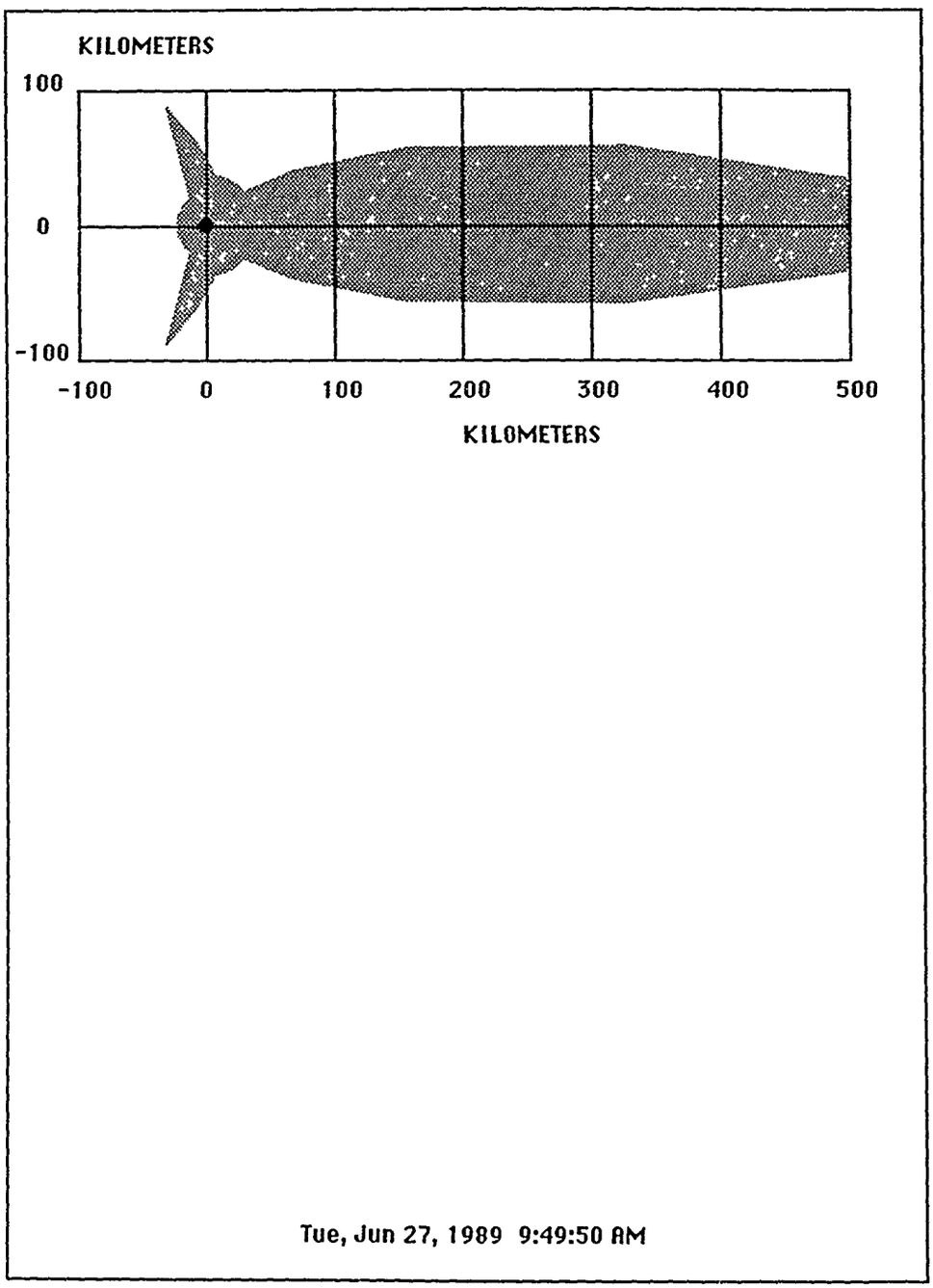

Figure 7. Vulnerability Contour, Page 1

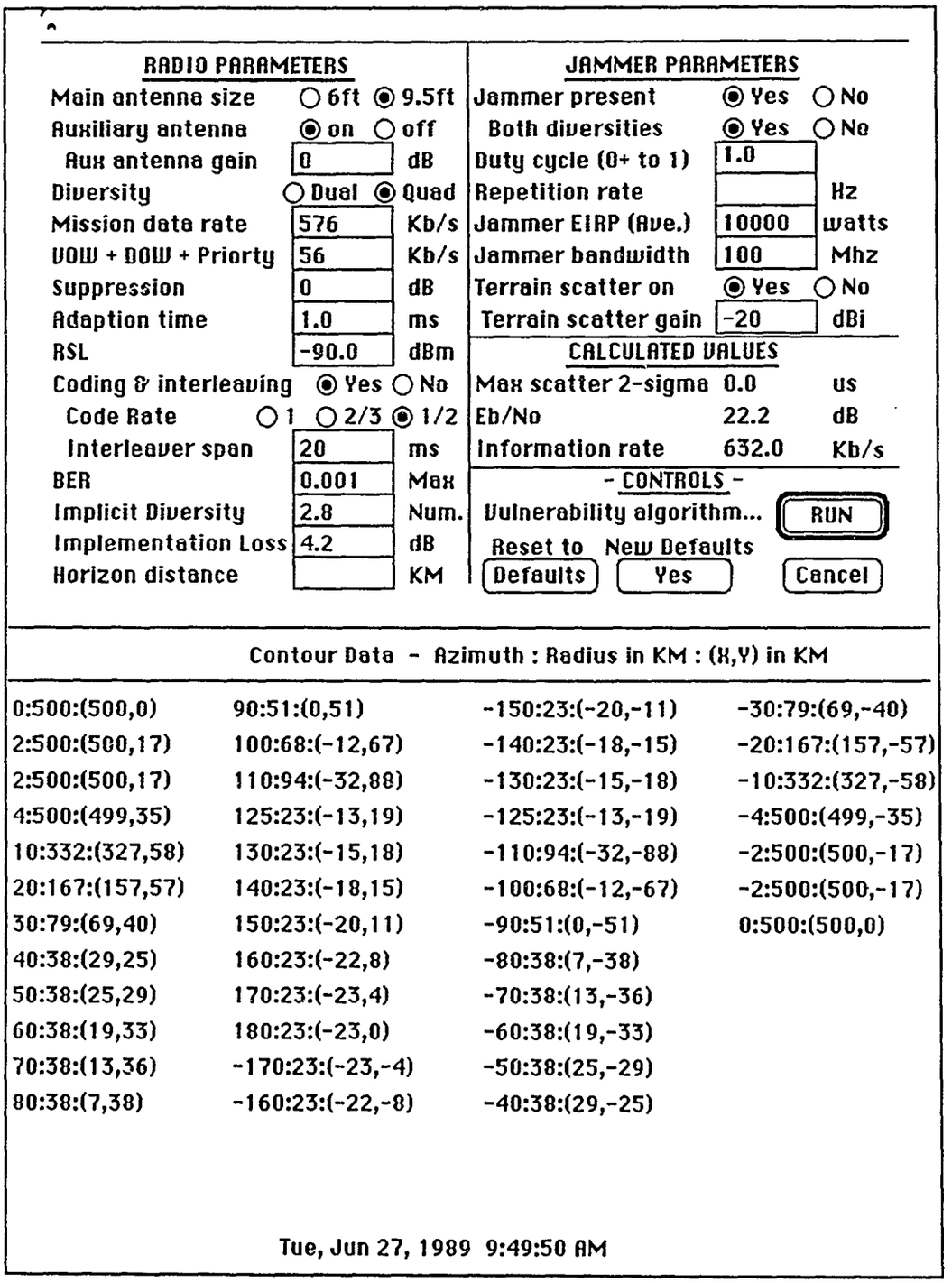

Figure 8. Vulnerability Contour, Page 2

SECTION 4

THE E_b/N_0 vs J_0/N_0 ALGORITHM

The E_b/N_0 vs J_0/N_0 algorithm is used to generate plots of E_b/N_0 vs J_0/N_0. The algorithm first selects the appropriate BER expression for the scenario which has been specified. Then, using this expression, the algorithm steps over a range of J_0/N_0 values searching at each step for the E_b/N_0 which yields a BER to within an accuracy of +0/-1 percent of the BER specified in the parameter selection dialog box. The range over which J_0/N_0 varies starts at the value specified as the average jammer power in the parameter selection dialog box and stops 100 dB below this value. The algorithm step size has been set to 5 dB increments. Therefore, there will be a maximum of 21 possible E_b/N_0 output values. Only E_b/N_0 values which yield a BER within +0/-1 percent of the target BER will be considered as valid output data by the algorithm. If no valid output data is found, a message to this effect is displayed.

To run the E_b/N_0 vs J_0/N_0 algorithm, first select the E_b/N_0 vs J_0/N_0 button in the algorithm selection dialog box, figure 2, and then activate the YES control button. The E_b/N_0 vs J_0/N_0 parameter selection dialog box will appear next with a predetermined set of default values for the radio and jammer parameters. Changes can now be made to any of these parameters, except that you cannot turn the jammer off. After the desired scenario has been selected, activate the RUN control button to start the calculations. While the calculations are in progress, a dialog box is displayed which contains a CANCEL control button, a 'Please wait ' message, and a circle which is periodically filled in to indicate the percentage of calculations complete. If the CANCEL button is activated while the calculations are in progress, the TropoComm program terminates and control is returned to the Macintosh operating system. When the algorithm completes all of the calculations, the screen is cleared and a text window with the output data is displayed.

4.1 The E_b/N_0 vs J_0/N_0 Parameter Selection Dialog Box

The E_b/N_0 vs J_0/N_0 parameter selection dialog box, figure 9, is partitioned into four sections: radio parameters, jammer parameters, calculated values, and control buttons. The radio parameters and jammer parameters sections permit specification of various scenarios. A more detailed discussion of these sections is provided below. The calculated values section is used to display the information rate for the scenario which was specified. The information rate is the data rate used when determining the received signal level for a calculated E_b/N_0 value. The control buttons section contains the name of the algorithm and four control buttons: the RUN button starts the E_b/N_0 vs J_0/N_0 calculations, the CANCEL button returns the program to the algorithm selection dialog box, the YES button changes the radio and jammer default values to the values currently shown in the parameter selection dialog box, and the DEFAULTS button resets all radio and jammer parameters to the default values.

Selecting various radio and jammer scenarios requires a change to the radio and/or jammer parameter default values. There are 16 E_b/N_0 vs J_0/N_0 radio parameters, and they are identical to the BER

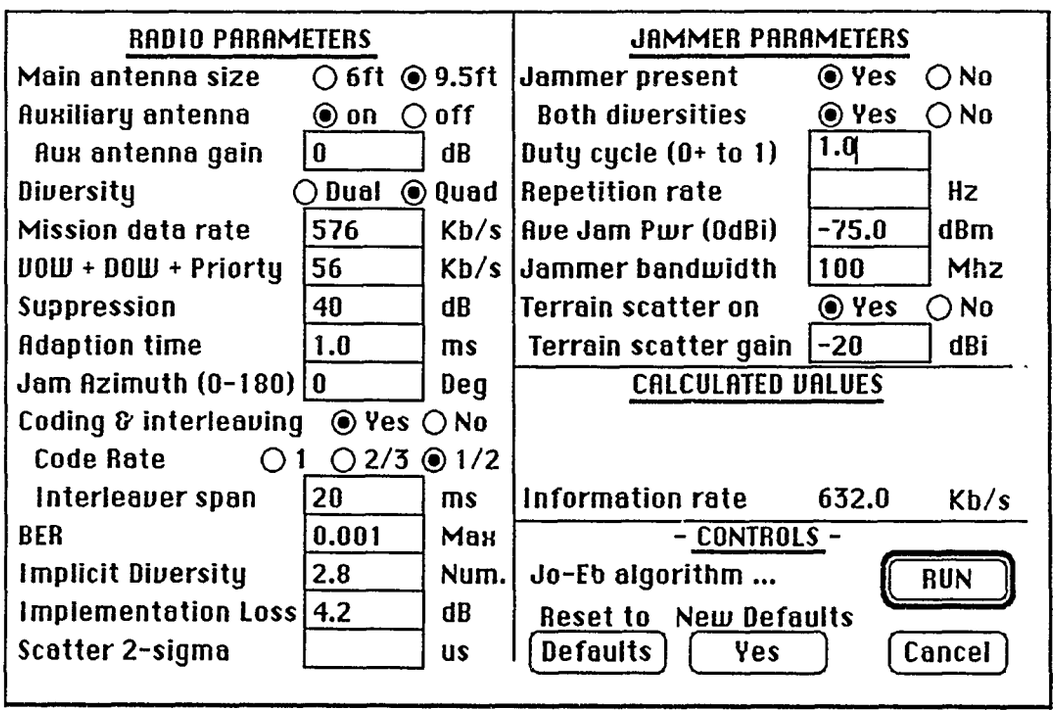

Figure 9. The E_b/N_o vs J_o/N_o Parameter Selection Dialog Box

radio parameters described earlier in section 2.1. There are eight E_b/N_0 vs J_0/N_0 jammer parameters, and they are identical to the BER jammer parameters described earlier in section 2.1.

4.2 E_b/N_0 vs J_0/N_0 Menu Options

When the E_b/N_0 vs J_0/N_0 calculations have finished, a text window with the output data is displayed. Each line of the output data contains three values: J_0 (dBm/Mhz) in a 0 dBI hypothetical reference antenna at the radio site, and J_0/N_0 (dB) and E_b/N_0 (dB) referred to the input of the receiver. If there is no valid output data due to the scenario specified, a message is displayed to this effect.

Associated with the text window are three menu options: the apple menu, the file menu, and the edit menu. The apple menu allows access to any of the desk accessories currently installed in the system. The file menu allows you to save a file, print the displayed data along with the scenario, or quit. When you save a file you will be given the option of saving a text file and/or a PICT file. Saving the text file enables you to transfer the output data into other Macintosh application. If the PICT file is saved, it will be saved as a MacDraw document and when activated later will open up as such. The MacDraw application program must be on the hard disk in order to open a MacDraw document. The PICT file is a picture of the E_b/N_0 vs J_0/N_0 parameter selection dialog box and the output data. The print command under the window file menu allows you to print the E_b/N_0 vs J_0/N_0 parameter selection dialog box and the output data while the text window is still displayed. For an example of the the print command output, see figure 10. The quit command, which is also under the window file menu, returns you to the parameter selection dialog box. The window edit menu allows you to cut, copy, and paste between the clipboard and the text window.

4.3 E_b/N_0 vs J_0/N_0 Output Graphics

Text files which have been created using the save command in the E_b/N_0 vs J_0/N_0 algorithm can be transferred directly into Cricket Graph by simply opening the text file while the application is running. This provides a convenient way to get the data from the E_b/N_0 vs J_0/N_0 algorithm to the Cricket Graph application.

To create a graph, first quit the TropoComm program and then activate the Cricket Graph application. In the Cricket Graph menu under "File", choose "Open file". Set the option to "show all text files". Open the file which was previously created by the E_b/N_0 vs J_0/N_0 algorithm. The data will automatically transfer into the Cricket Graph application, and an appropriate graph can be constructed and then saved, printed, or discarded. Using the output data in figure 10, an example of a graph which was created using Cricket Graph is shown in figure 11.

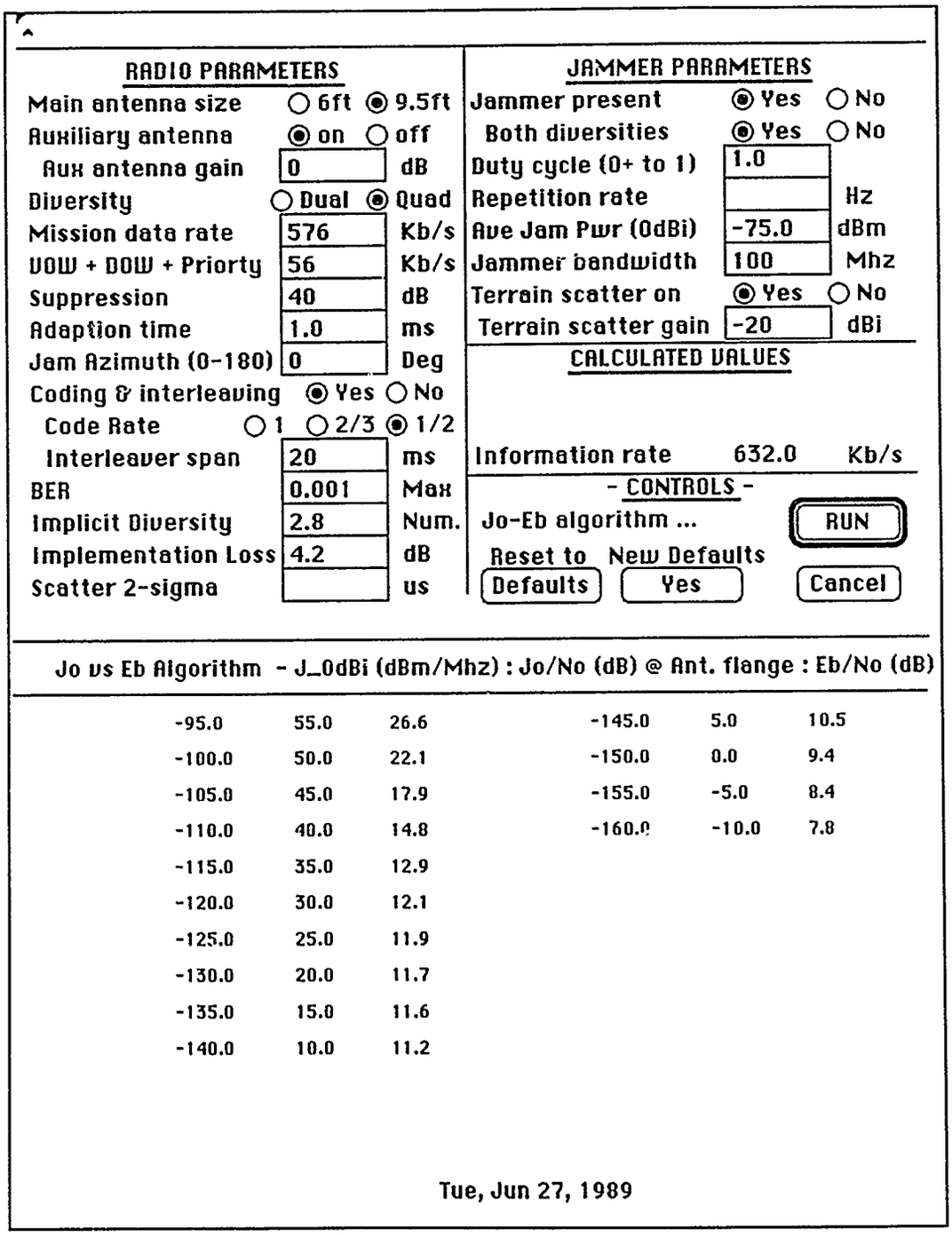

Figure 10. E_b/N_o vs J_o/N_o Print Command Output

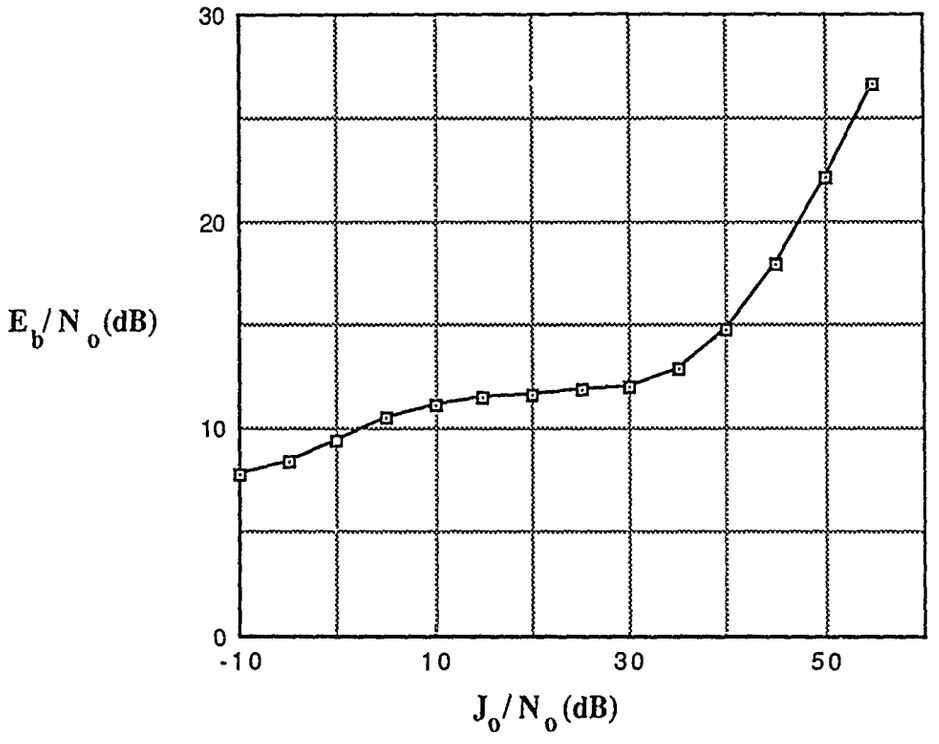

Figure 11. Plot of E_b/N_o vs J_o/N_o

SECTION 5

THE RHO ALGORITHM

The RHO algorithm is used to generate plots of E_b/N_0 versus jammer duty cycle. The algorithm first selects the appropriate BER expression for the specified scenario. Then using this expression, the algorithm steps over a range of jammer duty cycles searching at each step for the E_b/N_0 which yields a BER to within an accuracy of +0/-1 percent of the BER specified in the parameter selection dialog box. The range over which the jammer duty cycle varies is from 1 to 10^{-2}, or from 0 dB to -20 dB. The algorithm step size has been set to 1 dB increments. Therefore, a total of 21 E_b/N_0 output values are possible. Only E_b/N_0 values which yield a BER within +0/-1 percent of the target BER will be considered as valid output data by the algorithm. If no valid output data is found, a message to this effect is displayed.

To run the RHO algorithm, first activate the RHO button in the algorithm selection dialog box, figure 2, and then activate the YES control button. The RHO parameter selection dialog box will appear next with a predetermined set of default values for the radio and jammer parameters. Changes can now be made to any of these parameters, except that you cannot turn the jammer off. After the desired scenario has been selected, activate the RUN control button to start the calculations. While the calculations are in progress, a dialog box is displayed which contains a CANCEL control button, a "Please wait" message, and a circle which is periodically filled in to indicate the percentage of calculations complete. If the CANCEL button is activated while the calculations are in progress, then the TropoComm program terminates and control is returned to the Macintosh operating system. When the algorithm completes all of the calculations, the screen is cleared and a text window with the output data is displayed.

5.1 The RHO Parameter Selection Dialog Box

The RHO parameter selection dialog box, figure 12, is partitioned into four sections: radio parameters, jammer parameters, calculated values, and control buttons. The radio parameters and jammer parameters sections permit specification of various scenarios. A more detailed discussion of these sections is provided below. The calculated values section is used to display the information rate for the scenario which was specified. The information rate is the data rate used when determining the received signal level for a calculated E_b/N_0 value. The control buttons section contains the name of the algorithm and four control buttons. The RUN button starts the RHO calculations; the CANCEL button returns the program to the algorithm selection dialog box; the YES button changes the radio and jammer default values to the values currently shown in the parameter selection dialog box; the DEFAULTS button resets all radio and jammer parameters to the default values.

Selecting various radio and jammer scenarios requires a change to the radio and/or jammer parameter default values. There are 16 RHO radio parameters, and they are identical to the BER radio parameters described earlier in section 2. There are eight RHO jammer parameters and they are identical to the BER jammer parameters described earlier in section 2, except for the duty-cycle parameter which you can no longer specify.

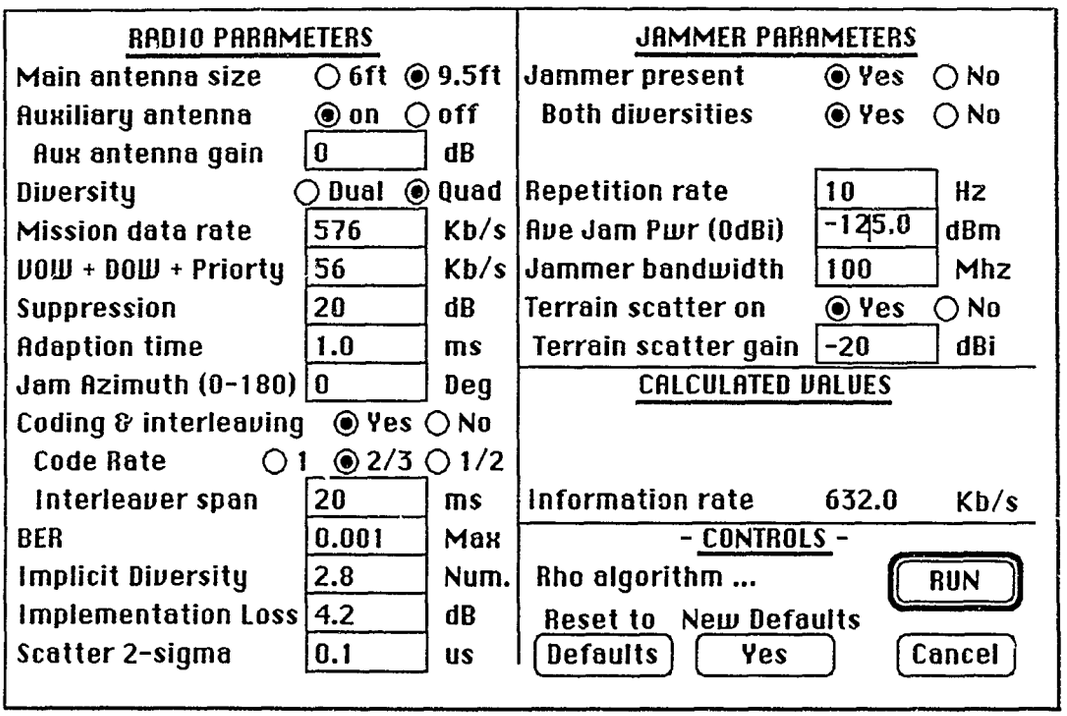

Figure 12 The RHO Parameter Selection Dialog Box

5.2 RHO Menu Options

When the RHO calculations have finished, a text window with the output data is displayed. Each line of the output data contains three values: duty cycle in dB, duty cycle in numeric form, and E_b/N_0 in dB. If there is no output data, a message is displayed to this effect.

Associated with the text window are three menu options: the apple menu, the file menu, and the edit menu. The apple menu allows you to access any of the desk accessories currently installed. The file menu allows you to save a file, print the displayed data along with the scenario, or quit. When you save a file you will be given the option of saving a text file and/or a PICT file. Saving the text file enables you to transfer the output data to another Macintosh application. If the PICT file is saved, it will be saved as a MacDraw document and, when activated later on, will open up as such; the MacDraw application program must be on the hard disk in order to open a MacDraw document. The PICT file is a picture of the RHO parameter selection dialog box and the output data. The print command under the window file menu allows you to print the RHO parameter selection dialog box and the output data while the text window is still displayed. For an example of the the print command output, see figure 13. The quit command, which is also under the window file menu, returns you to the parameter selection dialog box. The window edit menu allows you to cut, copy, and paste between the clipboard and the text window.

5.3 RHO Output Graphics

Text files which have been created using the save command in the RHO algorithm can be transferred directly into Cricket Graph by simply opening the text file while the application is running. This provides a convenient way to get the data from the RHO algorithm to the Cricket Graph application.

To create a graph, first quit the TropoComm program and then activate the Cricket Graph application. In the Cricket Graph menu under "File", choose "Open file". Set the option to "show all text files". Open the file which was previously created by the RHO algorithm. The data will automatically be transferred into the Cricket Graph application, and an appropriate graph can be constructed and then saved, printed, or discarded. Using the output data in figure 13, an example of a graph which was created using Cricket Graph is shown in figure 14.

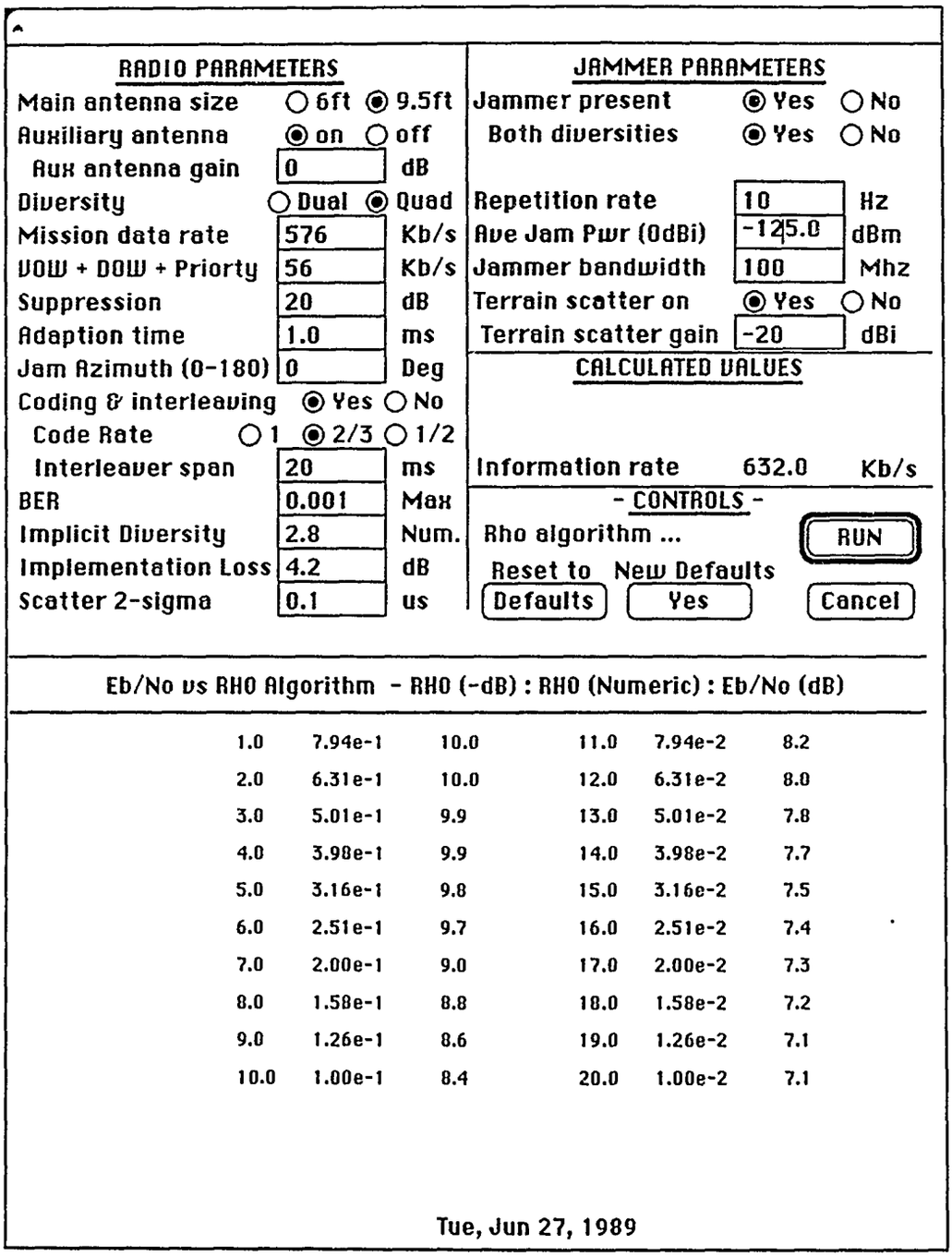

Figure 13. RHO Print Command Output

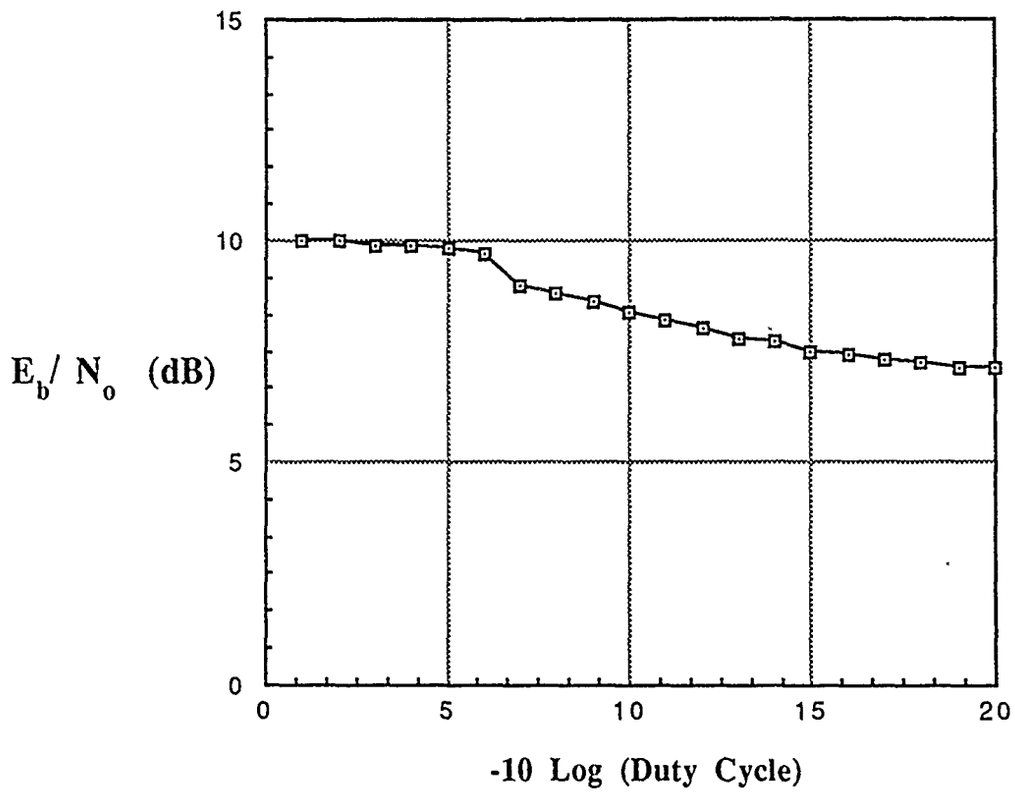

Figure 14. Plot of E_b / N_o vs Duty Cycle

SECTION 6

CONCLUSION

TropoComm has proven to be a useful tool. The program was initially developed to aid in the analysis of the various antijamming subsystems for the AN/TRC-170 radio to be proposed by contractors. It has also been used to create vugraphs for briefings to the Air Force Electronic Systems Division and MITRE management. One of the more useful features of TropoComm has proven to be its ability to create vulnerability contours. Vulnerability contour vugraphs can convey to an audience the expected differences in both standard and anti-jammed radio performance for the AN/TRC-170 in an ECM environment in a quick and understandable way.

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